Proximity Effects of High Voltage Transmission Lines on Humans

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Abstract— **Recently new threats to humans are observed from electromagnetic radiation from various sources like mobile phones, transmission lines and many more. For providing continuous and uninterrupted supply of electric power to consumer's maintenance operation of high voltage power lines are often performed with systems energized or live. This is referred as Hot Line maintenance or live line maintenance in this paper authors are concentrating on effects due to high voltage transmission lines on persons involved in this live line maintenance. The main aim of this paper is to create a model for health hazards in high voltage transmission lines. In this paper just a theoretical approach is presented, in coming days the model suggested will be prepared with ANSYS or MATLAB. The results of actual field reading will be compared with the mathematical model and will be presented as next part of research work.**

Keywords— **EHV lines, Power-Frequency Electro-Magnetic fields, Human Health, SAR, ANSYS, MATLAB.**

I. INTRODUCTION

Since last few decades electricity has become a vital part of our life and it is proving to be an integral part of modern life. The electricity system produces extremely low frequency electromagnetic field which comes under Non ionising radiations which can cause health effects. Apart from human effect, the electrostatic coupling & electromagnetic interference of high voltage transmission lines have impact on plants and telecommunication equipments mainly operating in frequency range below UHF.

Exposure of humans to electromagnetic fields from high voltage transmission lines is a great concern about humans since transmission lines are found everywhere in our environment. Each country has its own standard for exposure to EMFs based on guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The biological effect of these exposures is a subject of great interest to researchers. Some possibilities of leukemia have been reported [1] along with other health effects such as reproduction systems [2-3], variation in blood sugar contents [4], neuronal disorders such as alzheimer, depression [5-6] etc. the main reason of all these effects is alteration of Melatonin Secretation [7] as a result of EMF exposure [8]. Melatonin Secretion is involved in aging process [9], sleep orders & disorders [10], breast carcinogenesis [11], tumor genesis [12]. With growing population the human is approaching more towards transmission line, the distant transmission lines are now in close proximity to humans. The result studies related to proximity effects have taken two opposite ends resulting in ambiguity. Some conclusions had shown no harmful effects on humans whereas the recent one are agreeing on the bad effects on manmade electrical sources like HV transmission lines [13-14]. Some scientist have identified & studied the workplaces of possible risks [7, 15-17] & some had recommended to study other appliances along with transmission lines such as monitors, televisions, hairdryer copying machines etc [7].

An extensive literature survey was done on the above topic & authors observed a gap in relevant literature especially in India on hot line workers. The aim of proposed research is to make aware the government, government organizations & people coming in close proximity of TLS about possible health risks & ways to minimize the effects (if any) in near future.

II. HISTORY

Extremely high voltages in EHV lines cause electrostatic effects, where as short circuit currents & line loading currents are responsible for electromagnetic effects. The effect of these electrostatic fields is seen prominent with living things like humans, plants, animals along with vehicles, fences & buried pipes under & close to these lines. The following section will explain the electrostatic effects on

A. Human beings

When a person who is isolated from ground by some insulating material comes in close proximity to an overhead transmission line, an electrostatic field is set in the body of human being, having a resistance of about 2000 ohms. When the same person touches a grounded object, it will discharge through his body causing a large amount of discharge current to flow through the body. Discharge currents from 50-60 Hz electromagnetic fields are weaker than natural currents in the body, such as those from the electrical activity of the brain and heart.

For human beings the limit for undisturbed field is 15 kV/m, R.M.S., to experience possible shock. When designing a transmission lines this limit is not crossed, in addition to this proper care has been taken in order to keep minimum clearance between transmission lines.

A number of papers have been published to study the effects of high electrostatic field on human beings, as number of cases have already been registered indicating the effect of electrostatic field from transmission lines on human beings.

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B. Animals

Many researchers are studying the effect of e.s. field on animals. In order to do so they keeps the cages of animals under high e.s. field of about 30 kV/m. The results of these experiments are shocking as animals (are kept below high e.s. field their body acquires a charge & when they try to drink water, a spark usually jumps from their nose to the grounded pipe) like hens are unable to pick up grain because of chattering of their beaks which also affects their growth.

C. Plant Life

Plants which are in proximity of e.s. field due to transmission lines suffer from various types of damage depending upon the field strength. The main damage due to e.s. field is it prevents the full growth of the plant and grain.

D. Vehicles

When a vehicle is parked under high voltage transmission line an electrostatic field is developed in it. When a person who is grounded touches it a discharge current flows through the human being. In order to avoid this parking lots are located below the transmission lines the recommended clearance is 17 m for 345 kV and 20 m for 400 kV lines.

E. Others

For fences, buried cables, and pipe lines proper care has been taken to prevent them from charging due to e.s. field. When using pipelines which are more than 3 km in length & 15 cm in diameter they must be buried at least 30 laterally from the line center [29-30].

Effect of Power-Frequency Magnetic fields on human health: The energy stored by the magnetic field is given by

$$E = B^2/2\mu 0 \text{ Joules/meter}^3$$

Where B is in Tesla & $\mu 0 = 4$ it 10^{-7} H/m.

The magnetic field emanating from a electronic system has influence on tissues in the human body. These influences may be beneficial or harmful depending upon its nature, that they may be used for MRI, Citiscan etc. or may cause several types of cancers like: leukemia or blood cancer, lymphoma which weakens the immune system of body etc. It has been found that the magnetic radiation emanating from Video Display Terminals may cause skin rash, tissue cancer, eye problems and in many situations cause abortions in pregnant women's. Scientists around the world are now working on studying the health effects associated with magnetic field emanating from high voltage transmission lines.

It is believed that, the magnetic field might induce a voltage in the tissue of human body which causes a current to flow through it due to its conductivity of around 0.1 to 0.2 Siemens/meter. This is not the case for certain workers as the cell walls are made from protein acting as insulation barriers to the flow of current. In order to limit the magnetic field in homes or in occupations such as line workers, organizations like WHO, IRCA have given guidelines. In 1966, two Russian Scientists published their report on electricians working with electrical distribution lines (both males & females) experience breast cancer. They suspected that it may be due to magnetic field. Based on their report the Russian government recommended the following guidelines to limit the exposure of workers to the magnetic field.

TABLE I: GUIDELINES TO LIMIT THE EXPOSURE OF WORKERS TO THE MAGNETIC FIELD.

Exposure Hours	1	2	3	4	5	6	7	8
B-Field, Gauss	754	616	503	402	314	251	201	176

Same guidelines have been suggested by the number of international and national organizations. In case of general public this exposure limit is about 1 to 2 hours in public places. As per the guidelines given by WHO and IRPA, we can diagnose any cancerous or other internal health defects inside the body from the conditions on the surface of the body. They relate the measured current density on the body surface with following health hazards.

TABLE II: MEASURED CURRENT DENSITY ON THE BODY SURFACE WITH FOLLOWING HEALTH HAZARDS

Surface Current Density, mA/m^2	Health Effects
<1	Absence of any established effects.
1 – 10	Minor biological effects
10 – 100	Well established effects a) Visual defects. b) Possible nervous- system defects.
100 - 1000	Changes in central nervous-system excitability (onset of brain damage) established: Stimulations Thresholds; possible health hazards.
> 1000	Extra systoles; Ventricular fibrillation (heart condition); Definite health hazards.

Now we will derive the relation between surface current density measured on a cylindrical organ of radius r, electrical conductivity σ and the flux density at a frequency f as:

The flux density is

$$B(t) = \sqrt{2}\, B_{rms} \sin\omega t$$

Due to flux density B(t) a voltage v is induced in the cylinder of radius r,

i.e. $v = \pi r^2 \, dB/dt$

$$= 2\sqrt{2}\, \pi^2 f r^2 B_{rms} \text{ volts}$$

The resulting voltage gradient on the surface is

$$e = v/2\pi r$$

$$= \sqrt{2}\, \pi f r B_{rms}.$$

The rms value of surface current density is given by

$Jrms = \sigma erms$

$$= \pi f \sigma r B_{rms}, \text{ Amp/m}^2$$

Where Jrms = rms value of current density,

Brms = rms value of flux density in Tesla,

f = frequency in Hz,

σ = electrical conductivity of the tissue, Siemens/meter,

and r = radius of the cylinder, meter.

During Research on health effects of electric and magnetic fields, it has come forward that electric field intensity exposure of about 1-10 mv/m in tissue interact with cells but not proved to be harmful. But strong fields cause harmful effects when their magnitude exceeds stimulation thresholds for neural tissues (central nervous system and brain), muscle and heart.

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The government all the countries deal with the situation seriously and scientifically. They limit the electromagnetic field intensity in various environments by laws & regulations to guarantee people's normal life [18]. In India it is stipulated that electric field intensity should not exceed 4.16 kV/m and magnetic field intensity should not exceed 100μT in public areas. There is stronger electromagnetic field radiation around extra high voltage overhead transmission line.EMF distribution in the human body is the main aspect to study proximity biological effects of power transmission lines. Many studies have undergone for EMF distribution under extra high voltage transmission lines without & with thinking of human.

Highest exposures to these radiated electromagnetic fields occur in an occupational setting in the vicinity of current carrying conductors. In association to this various studies have been done with live line workers with or without wearing metallic shielding suit. Apart from intensities of field the distance between radiating source & exposed human can also be a critical factor in biological effects. Person driving a car, person seating in a bus, driver driving electro locomotive, guided automobiles passing on a flyover are the different situations that can be considered under this category. The work reported have will consider the short term impact on human involved in above situations, resulting from electric fields. Authors are recommending a method to calculate three dimensional EMF distributions in a maintenance personal body.

III. MODEL

For providing continuous and uninterrupted supply of electric power to consumers maintenance operations of power lines are often performed with systems energized or live. This is live line maintenance or hot line maintenance. The electric fields and magnetic fields associated with these power lines may affect the health of live line workers. Its electric field and current densities affect the health of humans and cause several diseases by affecting majority parts of the human body. These electric field and current densities affects humans of all stages and causes short term diseases in them and sometimes death also. The human body is a complex three dimensional structure and is composed of seventeen kinds of biological materials like blood, bone, brain, lungs, muscle, skin etc. The permeability of human body is equals to permeability of air but σ & μ within a human body has different electromagnetic values at a certain frequency for different material [18]. Similarly variation will be for metallic structure around human body.

Generally in maximum studies exposure field is treated as uniform but in some situations when human body is close enough to a charge conductor so that exposure field cannot be represented as uniform. The same exposure electric field 1m above ground for a line source 4m above the ground and a human body under the line induces greater electric fields in all organs than those induced by the same uniform field [19]-[27]. The main difference between electric & magnetic field at power line frequencies is that the exposure electric field is perturbed by human & other conducting bodies, while the magnetic fields remains unchanged in the free space as well as in the human body. But it will vary in metallic body. Both fields induce electric fields & currents therefore if these quantities are responsible for biological interactions both Fields produce similar effects.

While reviewing the recent works, it is noticed that only few works in the literature deals with actual problem and simulation is not done properly by them and they have just calculated the electric field and current density values and compared them with standard values and have not generated any model. They cannot measure the values directly from human body, but instead use some other process to measure them. The existing works have failed to achieve the exact model. These problems motivated to find a solution and to perform this research work.

The main aim of this paper is to create a model for health hazards in hot line maintenance using graphical method. Electric field and current density will be the two factors that will be considered for generating the model. By overcoming the problems explained above, here we propose a new method using graphical analysis method for generating the model. Polynomial equation will be generated for electric field and current density and another equation will be generated for actual field data and by equating both the equations a new model will be generated. The newly generated model will be then compared with the IEEE standard value limit of the current density value. Simulation will be done for electric field and current density using graphical method. Actual study will be conducted by measuring EMFs at various identified locations. The measurement from this survey will be compared with the standard limits shown in table III. These guidelines were given in ICNIRP & updated recently [7]. The distance from source, sag in transmission lines will be the important parameters in measurement. The instrument that authors have identified for EMF measurement is M/E analyzer for the low frequency, model no. ME 3830. With the help of this device we can measure frequencies from 16 Hz to 100 kHz.

TABLE III: SUMMARY OF ICNIRP (1998) AND COUNCIL OF EUROPEAN UNION (1999) EXPOSURE GUIDELINES

Power lines		
Frequency	50 Hz	50 Hz
	Electric Field (V/m)	Magnetic Field (μT)
Public exposure limits	5000	100
Occupational exposure limits	10000	500

It can be assumed that the transmission lines are infinite long cylindrical conductors, which have the same constant radius & moving parallel to each other & ground. Electrical charge & current in the transmission line is assumed to be at the centre of lines since distance from lines to the human is much larger than radius of the line [18]. Biological materials of the human body are taken as isotropic. Both AC & DC power systems can be dealt with above model.

IV. D.C TRANSMISSION SYSTEMS

Determining the electric field when the charge distribution is not known comes under the class of boundary value problems since the known quantity is the specification of the

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potential over boundaries of some region. D.C. power lines generate static electric & magnetic field surrounding and in human body respectively.

The poisons equation for electric field is given as

$$\nabla^2 v = - \rho_v / \varepsilon$$

Where v is electric potential & ρ_v is electric charge density the current density in the human body can be calculated as follow.

$$J = \sigma E$$

Where σ is the conductivity of the human body.

But when charge distribution is suddenly unbalanced within conducting material, no charge and no electric field may exist at any point within a conducting material. If the external electric field intensity is divided into two components, one tangential and one normal to the conductor surface, the tangential component is seen to be zero. In nonzero case a tangential force would be applied to the elements of the surface charge, causing non static conditions.

The tangential field will be determined by applying

$$\int E \cdot lL = 0$$

The desired boundary conditions for the conductor free space boundary in electrostatic are

$$D_t = E_t = 0$$

$$D_N = \varepsilon_0 E_N = P_S$$

The electric flux leaves from the conductor in a direction normal to the surface and the value of the electric flux density is numerically equal to the surface charge density [28].

Number of quantities can be determined by using above equations but with considering following principles.

1) The static electric field intensity inside a conductor is zero where as at the surface of the conductor is everywhere directed normal to that surface.

2) The conductor surface is equipotential surface.

The above equations will be solved with reasonable mesh. The magnetic field equation is

$$\nabla^2 A = - \mu_0 J$$

Where A is magnetic vector potential, ì is permeability & J for current density. Current density is non zero only in the power lines.

All the equations will be solved in three stages

Solve electric & magnetic field equation for whole region.

Extract the values of V & A at the surface of the metal body.

Then solve for leakage current density J & flux density B in the body.

$$B = \nabla \times A$$

V. AC POWER TRANSMISSION LINES

Here effect will be similar except that a time changing magnetic field produces an electric field. The influence of the variation of electric field on the magnetic field can be neglected [18]. To calculate the current, we can use ampere's circuital law in point form as

$$\nabla \times H = J + \delta D/\delta t$$

Where H is magnetic field intensity, J is induced electric current density and addition term δD/δt has the dimensions of current density, amperes per square meter. Parameters of overhead transmission lines can be assumed as

TABLE IV: PARAMETER OF THE TRANSMISSION LINES

	Voltage (KV)	Current (A)	H (m)	L (m)
D.C. Lines	±500	±700	14	14
A.C. Lines	400	700	14	14

H is distance between the center of the lines & the ground L is the distance between the two lines.

With above model of transmission lines EMF distribution in the human body can be calculated under AC and DC Transmission lines [18].

READING TO BE TAKEN

Maximum & minimum values of magnetic & electrical field will be evaluated & will be compared with the limits given by various organizations like WHO, IEEE, ICNIRP etc. Specific Absorption Rate (SAR) can also be analyzed to study heating effects.

REFERENCES

[1] Portier, C. J., Wolfe, M.S., (1998). Assessment of health effects from exposure to power-line frequency electric and magnetic fields (working group report), Research Triangle Park, NC: National Institute of Environmental Health Sciences of the National Institutes of Health, (NIH publication 98-3981).

[2] Hatch, M., (1992). The Epidemiology of electric and magnetic field exposure in the power frequency range and reproductive outcomes, Paediatr Perinat Epidemiol, **6(2):** 198-214.

[3] Roychoudhury, S., Jedlicka, J., Parkanvi, V., Rafa, J., Ondruska, L., Massanyi P., Bulla, J., (2009). Influence of a 50 Hz extra low frequency electromagnetic field on spermatozoa motility and fertilization rates in rabbits, J Environ. Sci. and Health Part A **44:** 1041-1047.

[4] Abbasi M., Nakhjavani, M., (2002). Biological effects of magnetic fields: Field effect on reducing blood sugar in mice. Iran. Mag. Diabetes and Lipid **2(1):** 59-63.

[5] Sobel, E., Dunn, M., Davanipour, Z., (1996). Elevated risk of Alzheimer's disease among workers with likely electromagnetic field exposure, Neurology, **47:** 1477-1481.

[6] Verkasalo, P. k., Kaprio, J., Varjonen K., (1997). Magnetic fields of transmission lines and depression, Am J Epidemiol, **146:** 1037-1045.

[7] H. Ahmadi, S. Mohseni, A. A. Shayegani Akmal, Electromagnetic Fields near Transmission Lines – Problems and Solutions, Iran J. Environ. Health. Sci. Eng., 2010, Vol. 7, No. 2 pp. 181-188.

[8] Reiter, R. J., (1993). Electromagnetic fields and melatonin production, Biomed Pharmacother, **47:** 439-444.

[9] Poeggeler, B., Reiter, R. J., Tan, D. X., (1993). Melatonin Hydroxyl radical-mediated oxidative damage and aging: A Hypothesis, J Pineal Re, **14:** 15 1-168.

DOI: 01.IJEPE.03.01. 11

[10] Brzezinski, A, (1997). Melatonin in humans, N Engl J Med, **336(3):** 186-195.
[11] Blask, D. E., (1997). Systemic, Cellular and molecular aspects of melatonin action on experimental breast Carcinogenis. In: Stevens, R.G., Wilson, B.W., Anderson LE, the Melatonin Hypothesis: Breast Cancer and Use of Electric Power, Columbus, OH: Battelle Press 189-230.
[12] Fedrowitz, M., Loscher, W., (2008). Exposure of Fischer 344 rats to a weak power frequency magnetic field facilitates mammary tumorigenesis in the DMBA model of breast cancer. Carcinogenesis **29:** 189-193.
[13] Sher, L., (1997). Effects of natural and man-made electric/ electromagnetic fields on human health: a possible mechanism, Journal of Medical hypotheses, **49:** 31-34.
[14] Huss, A, Spoerri, A, Egger, M, Roosli, M., (2009). For the Swiss national cohort study Residence near power lines and mortality from neurodenerative diseases: longitudinal study of the Swiss population. Am. J. Epidemiol., **169(2):** 167-175.
[15] Akbar Khanzadeh, F., (1982). Biological effects of magnetic fields and assessing the magnetic field intensity in aluminum workshop, Iran. J. Pub. Health, **3**: 59-73.
[16] Garcia, A. M., Sistemas, A., Hoyos, S. P., (2008). Occupational exposure to extremely low frequency electric and magnetic fields and Alzheimer disease: a meta-analysis. Int. J. Epidemiol. **37(2):** 329-340.
[17] Zahiroddin, A. R., Shafiee Kandijani, A. R., Mahdavi Hezayeh, N., (2006). Mental health status of employees in substations of electromagnetic fields at extremely low frequency in Tehran. Iran. J. Environ. Health. Sci. Eng., **3(3):** 217-221.
[18] Hu Yu, Bai Baodong and Xie Dexin, "The Electromagnetic Field Distribution in the Human body umder the Ultra-High Voltage Transmission Lines", IEEE 2002 pp. 2243-2246.
[19] M. E. Potter, M. Okoniewski, and M. A. Stuchly, "Low frequency finite difference time domain (FDTD) for modeling of induced fields in humans close to line-sources", to be published.
[20] A. Taflove, *Computational Electrodynamics: The Finite-Difference Time-Domain Method*. Norwood, MA: Artech House, 1995.
[21] J. De Moerloose, T.W. Dawson, and M. A. Stuchly, "Application of the finite-difference time-domain algorithm to quasistatic field analysis," *Radio Sci.*, vol. 32, pp. 329–341, 1997.
[22] K.-M. Chen, H.-R. Chuang, and C.-J. Lin, "Quantification of interaction between ELF-LF electric fields and human bodies," *IEEE Trans. Biomed. Eng.*, vol. BME-33, pp. 1273–1276, 1986.
[23] P. J. Dimbylow, "Current densities in a 2mm resolution anatomically realistic model of the body induced by lowfrequency electric fields," Phys. Med. Biol., vol. 45, 2000, to be published.
[24] C. M. Furse and O. P. Gandhi, "Calculation of electric fields and currents induced in a mm-resolution human model at 60 Hz using the FDTD model," *Bioelectromagnetics*, vol. 19, pp. 293–299, 1998.
[25] T. W. Dawson, J. De Moerloose, and M. A. Stuchly, "Hybrid finite-difference method for high-resolution modeling of low-frequency electric induction in humans," *Computat. Phys.*, vol. 136, pp. 640–653, 1997.
[26] J.-P. Berenger, "Perfectly matched layer for the FDTD solution of wave-structure interaction problems," *IEEE Trans. Antennas Propagat.*, vol. 44, pp. 110–117, 1996.
[27] M. E. Potter, M. Okoniewski, and M. A. Stuchly, "Extension of the FDTD method to nonuniform excitation," *Electron. Lett.*, vol. 3, pp. 2216–2217, 1998.
[28] William H. Hayt, Jr. John A. Buck, "Engineering Electromagnetics", McgrawHill, 6th Edition.
[29] Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering" Edition, 3. Publisher, New Age International Pub., 2006.
[30] C. L. Wadhwa, "High Voltage Engineering", New Age International Pub., 2006.

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